Software Diversification for WebAssembly

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Abstract

WebAssembly, now the fourth officially recognized web language, enables web browsers to port native applications for the Web. Furthermore, WebAssembly has evolved into an essential element for backend scenarios such as cloud computing and edge computing. Therefore, WebAssembly finds use in a plethora of applications, including but not limited to, web browsers, blockchain, and cloud computing. Despite the emphasis on security since its design and specification, WebAssembly remains susceptible to various forms of attacks, including memory corruption and side-channels. Furthermore, WebAssembly has been manipulated to disseminate malware, particularly in cases of browser cryptojacking.

Web page resources, including those containing WebAssembly binaries, are predominantly served from centralized data centers in the modern digital landscape. Thousands of edge devices, in conjunction with browser clients, operate millions of identical WebAssembly instantiations every second. This phenomenon creates a highly predictable ecosystem, wherein potential attackers can anticipate behavior either in browsers or backend nodes. Such predictability escalates the potential impact of vulnerabilities within these ecosystems, paving the way for high-impact side-channel and memory attacks. For instance, a flaw in a web browser, instigated by a defective WebAssembly program, holds the potential to affect millions of users.

This thesis aims to bolster the security within the WebAssembly ecosystem through the introduction of Software Diversification methods and tools. Software Diversification is a strategy designed to augment the costs of exploiting vulnerabilities by making software unpredictable. The unpredictability within ecosystems can be diminished by automatically generating various program variants. These variants strengthen observable properties that are typically used to launch attacks, and in many instances, can completely eliminate such vulnerabilities.

This work introduces three tools: CROW, MEWE, and WASM-MUTATE. Each tool has been specifically designed to tackle a unique facet of Software Diversification. We present empirical evidence demonstrating the potential application of our Software Diversification methods to WebAssembly programs in two distinct ways: Offensive and Defensive Software Diversification. Our research into Offensive Software Diversification in WebAssembly unveils potential paths for enhancing the detection of WebAssembly malware. On the other hand, our experiments in Defensive Software Diversification show that WebAssembly programs can be hardened against side-channel attacks, specifically the Spectre attack.

Keywords: WebAssembly, Software Diversification, Side-Channels

Sammanfattning

LIST OF PAPERS

1. ***WebAssembly Diversification for Malware Evasion***
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Contents

Part I

Thesis